

INVESTIGATION OF VACUUM PUMPING
ON BEDS OF SOIL MATERIALS

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Abstract

The purpose of the investigation was to determine the pumping load and time required if beds of soil materials are placed in a vacuum chamber. The vacuum chamber used had a volume of approximately four cubic feet and could be pumped down to 10^{-8} torr when empty. Various sizes of soil beds were placed in the chamber. The beds were composed of either 500 micron or 5 micron particles of aluminum oxide. No particular difficulty was encountered in pumping beds of dry material (less than 0.1 percent moisture). A bed of fine material with 0.5 percent moisture erupted violently, due to sudden release of the moisture from the bed.

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MOON SOIL INVESTIGATION CONTRACT NAS1-5434

PURPOSE OF THE INVESTIGATION

The purpose of the investigation was to determine the pumping load and time required if moist soil is introduced into a vacuum chamber, and the value of predrying the soil before introduction into the chamber.

DESCRIPTION OF TEST EQUIPMENT

The vacuum system used to perform these experiments is shown in Fig. 1. It consists of a 5 cfm mechanical pump, a 1500 liter/sec diffusion pump, dry pass liquid nitrogen trap, and an 18" diameter x 30" high chamber. The ultimate pressure of the system clean, dry and empty is less than 1×10^{-8} torr. In the first tests 500 micron aluminum oxide was used. A photomicrograph of the material is indicated in Fig. 2. The particle size consisted of an approximate Gaussian distribution of particle sizes centered on 500 microns with a standard deviation of approximately 130 microns.

The second set of tests were performed with a 5 micron aluminum oxide "soil" supplied by NASA Langley Research Center.

MECHANICAL EFFECTS

In this series of tests the above system was modified in two respects. A plate was placed between the chamber and the liquid nitrogen trap to minimize cleaning that might be required as a result of a sample eruption. In addition a large mechanical pump (15 cfm) was connected to the chamber for high speed pumpdown. A typical pumpdown is indicated in Fig. 3. In addition a gauge was used to measure the pressure

at the bottom of the bed. A bourdon gauge was used for this purpose. In all cases, the pressure differential between the bed surface pressure and the pressure at the bottom of the bed was zero psi. A pressure difference of approximately 1/4 to 1/2 psi could have been detected. This was true in the case of the 500 micron and of the 5 micron soils.

Movies were taken at a speed of 16 frames per second on 16mm black and white film to show the effects of pumpdown on the soil. The pressures at the bottom of the bed and in the chamber are shown in the movies. Pressure time data can be obtained from the film but in no case did it differ substantially from that shown in Fig. 3. Approximately 12 ft³/min pumping speed was available for evacuating the chamber.

The following size containers were used to evaluate the mechanical effects on the soil:

<u>Diameter in Inches</u>	<u>Bed Length in Inches</u>
9.8	4.9
12.4	6.2
13.4	5.4
14.7	4.4
15.6	7.8
16.9	3.4
16.9	8.4

Loosely packed or tamped soil resulted in an approximate .5 theoretical density of material.

MOISTURE EFFECTS

The setup as shown in Fig. 1 was used to determine the outgassing rate of the soil at various water loadings. The plate separating the liquid nitrogen trap from the chamber was removed to permit complete system operation. A small 5 cfm pump was used for backing the diffusion pump and roughing the chamber. The evacuation of the chamber was done automatically resulting in the liquid nitrogen trap becoming cold (100° K or lower) within 2 minutes after startup.

Pumping speeds of the system are tabulated:

<u>Pressure Range</u>	<u>Gas</u>	<u>Speed</u>
760 to .76 torr	Air	2 liter/second 6 liter/second in the case of the large pump
.0076 to 10^{-8} torr	Air	540 liter/second
1 to 10^{-8} torr	Water Vapor	2700 liter/second

Fig. 6 indicates the estimated pumping speed (on the right hand ordinate) as a function of time.

The data for the outgassing rate as a function of time is indicated on Figs. 4 and 5. Fig. 4 indicates the difference between the outgassing rate as a function of time for 500 micron soil in the "as received" condition and after adding 1% water to the sample. There are two runs for the 1% water-loaded condition. One indicates outgassing rate as a function of time for the soil in the 16.9" diameter container. The 16.9" diameter container was resting on the inside walls of the 18" diameter chamber and, therefore, was insulated rather well from receiving heat. In the other run, the soil was placed

in the bottom of the chamber. Heat from the surrounding environment could be readily absorbed. Therefore, the temperature of the "insulated" soil was probably lower due to evaporative cooling resulting in a lower but longer term outgassing rate. Apparently, from the indicated data, most of the water from the "non-insulated" sample had already been removed and the outgassing rate is decreasing faster than the "insulated" sample.

Fig. 5 indicates the outgassing rate as a function of time for the 5 micron soil.

Mass spectrums indicated greater than 90% water vapor at a pressure of 1×10^{-5} torr as the outgassing specie.

DISCUSSION OF ERUPTION

No surface motion was detected in any of the runs except in the 5 micron soil loaded with .5% water vapor. In this case a very violent eruption took place. Pictures of the soil after the eruption are indicated in Figs. 7, 8 and 9. Fig. 8 is a closeup of the area in Fig. 7. Blowholes can be seen quite clearly in the base of the crater. Fig. 9 shows the pattern of the eruption on the chamber side walls. This occurred after seven minutes of pumping. Fig. 6 indicates the pressure to be approximately 1 torr at the time of the eruption. The air partial pressure at the time was extremely low.

The system pumping speed for the gases present in the chamber is 2 liter/sec from 760 torr to 1 torr. At this point the LN_2 trap is cold; in addition the gas composition in the chamber changes from predominately air to predominately water vapor. This means in the range 1 to 10 torr, the system speed changes drastically from 2 liter/sec for air to 2700 liter/sec for water vapor. At this point, the system pressure is still in the continuum range and has the high pumping speed of 2700 liter/sec. Violent boiling or "aggregative fluidization" took place in just this range.

RECOMMENDATIONS

As a result of the above experiments several recommendations can be made:

1. Eruptions of the soil appear to be associated with water vapor pumping speed and the water loading of the soil. To avoid eruptions the soil must contain less than .1% water vapor.
2. The outgassing products from the soil consist of more than 90% water vapor. Therefore, to achieve low pressures, large pumping speeds for water vapor are necessary. An outgassing rate of $3.6 (10^{-5})$ torr liter/sec-in² for the 5 micron soil, $7.7 (10^{-5})$ torr liter/sec-in² for the 500 micron material was measured after 24 hours of pumping for the "as received" material.



PHOTOGRAPH OF TEST EQUIPMENT

Fig. 1



Al₂O₃ Particles, 50X.

Fig. 2

Typical Pressure Time Data for Evaluation
of Mechanical Effects.

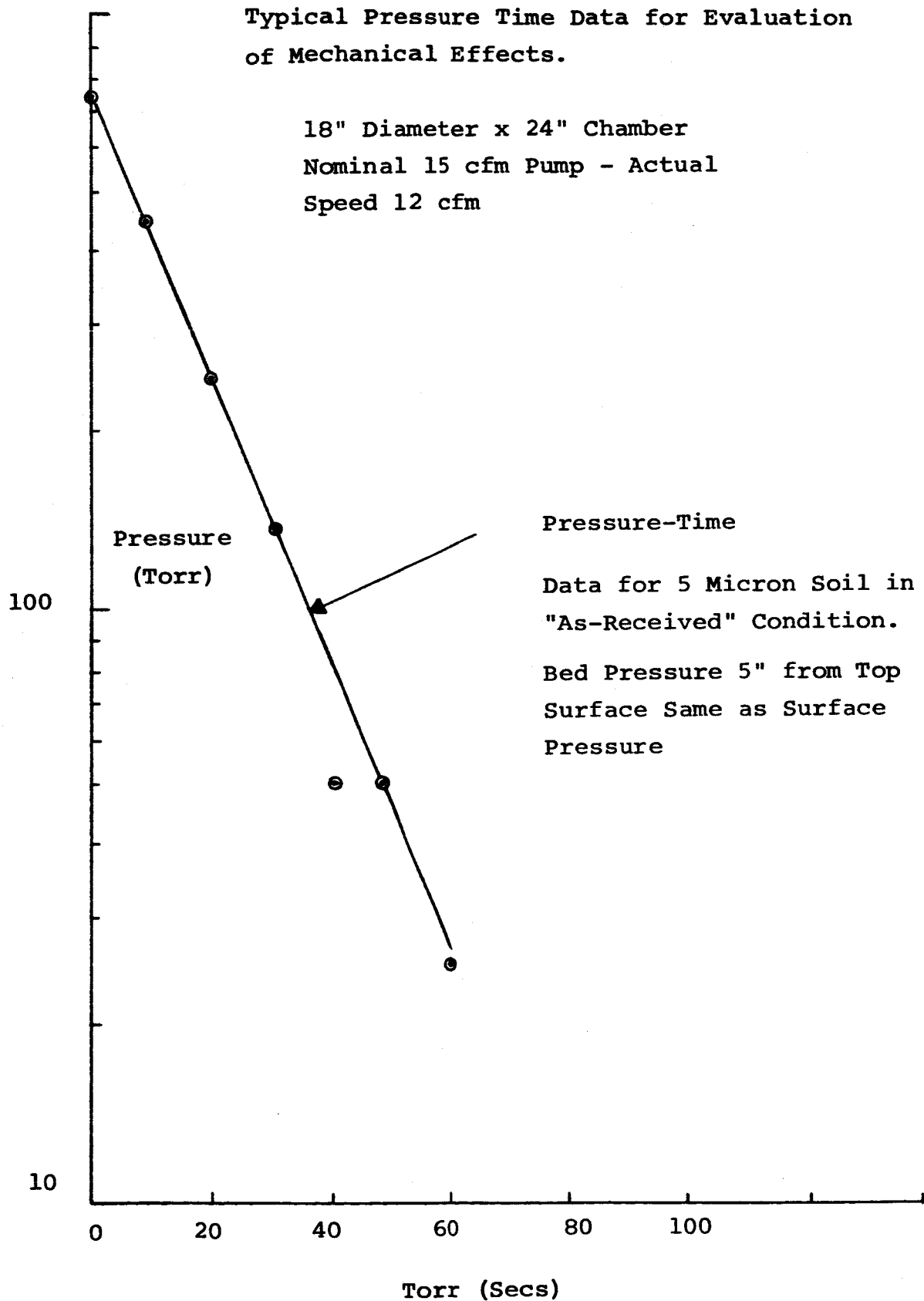


Fig. 3

OUTGASSING DATA

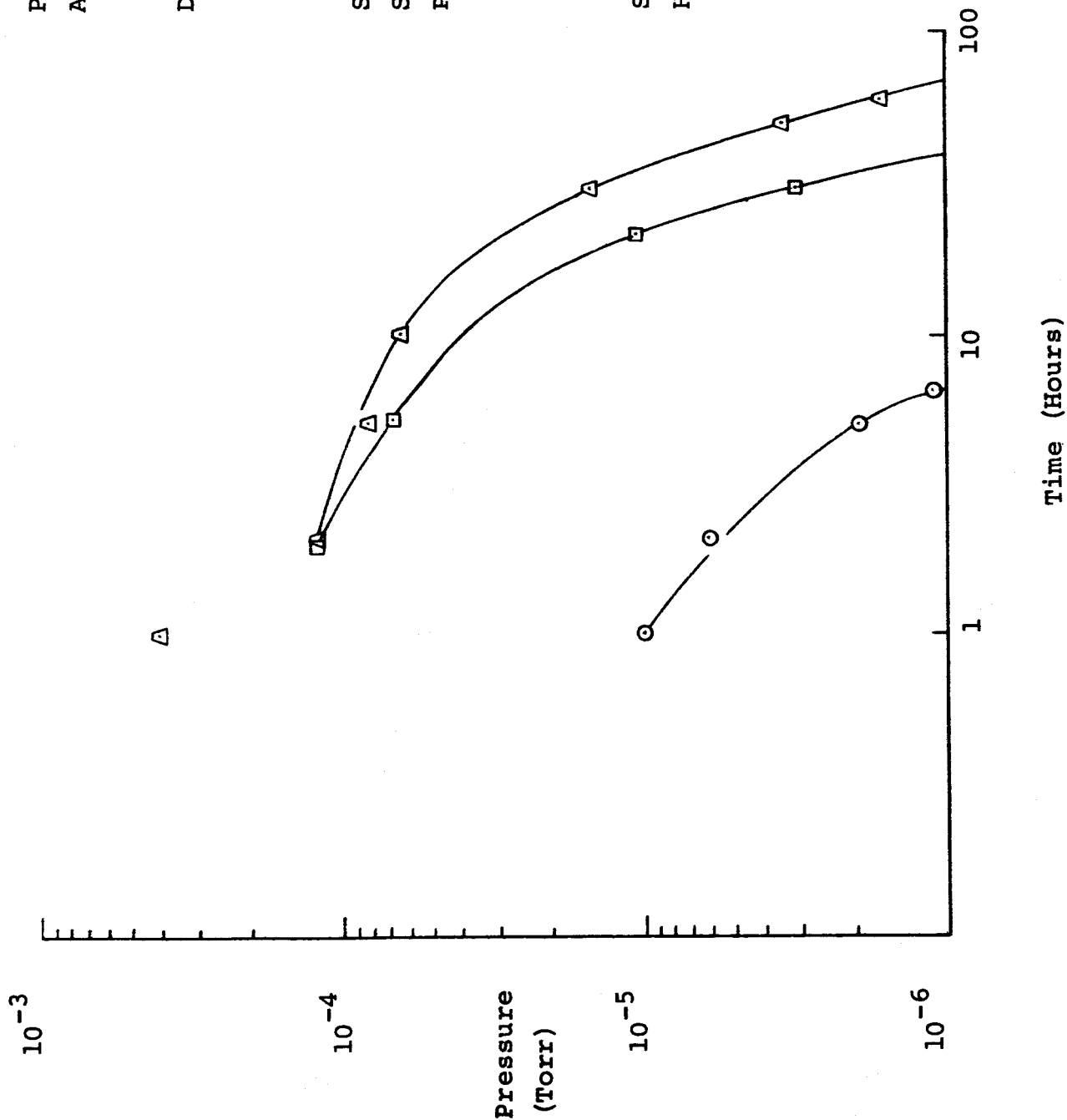
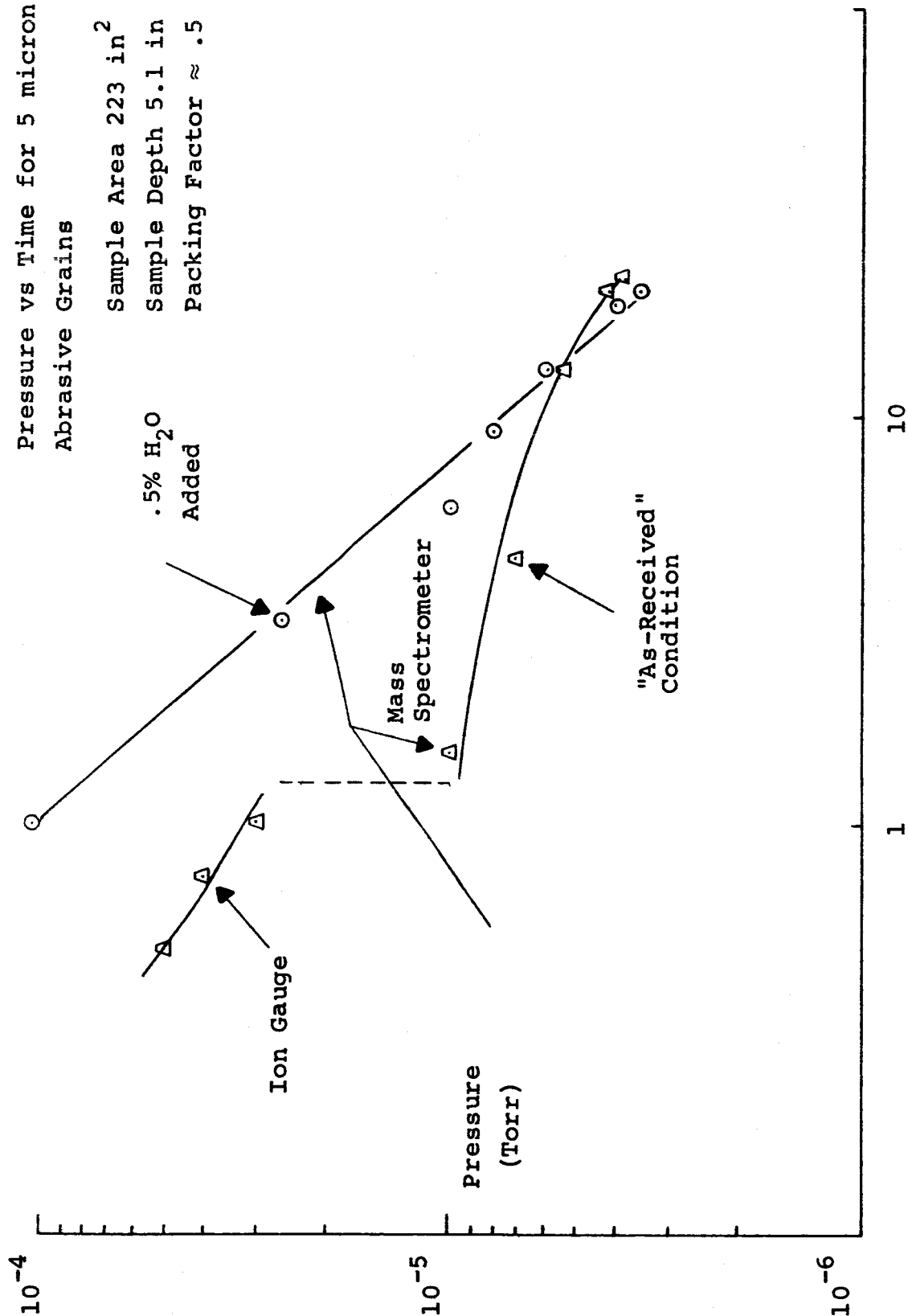


Fig. 4

OUTGASSING DATA

Spectrometer Indicates > 90% H₂O Vapor
Pressure vs Time for 5 micron Al₂O₃
Abrasive Grains

Sample Area 223 in²
Sample Depth 5.1 in
Packing Factor ≈ .5



Time (hours)

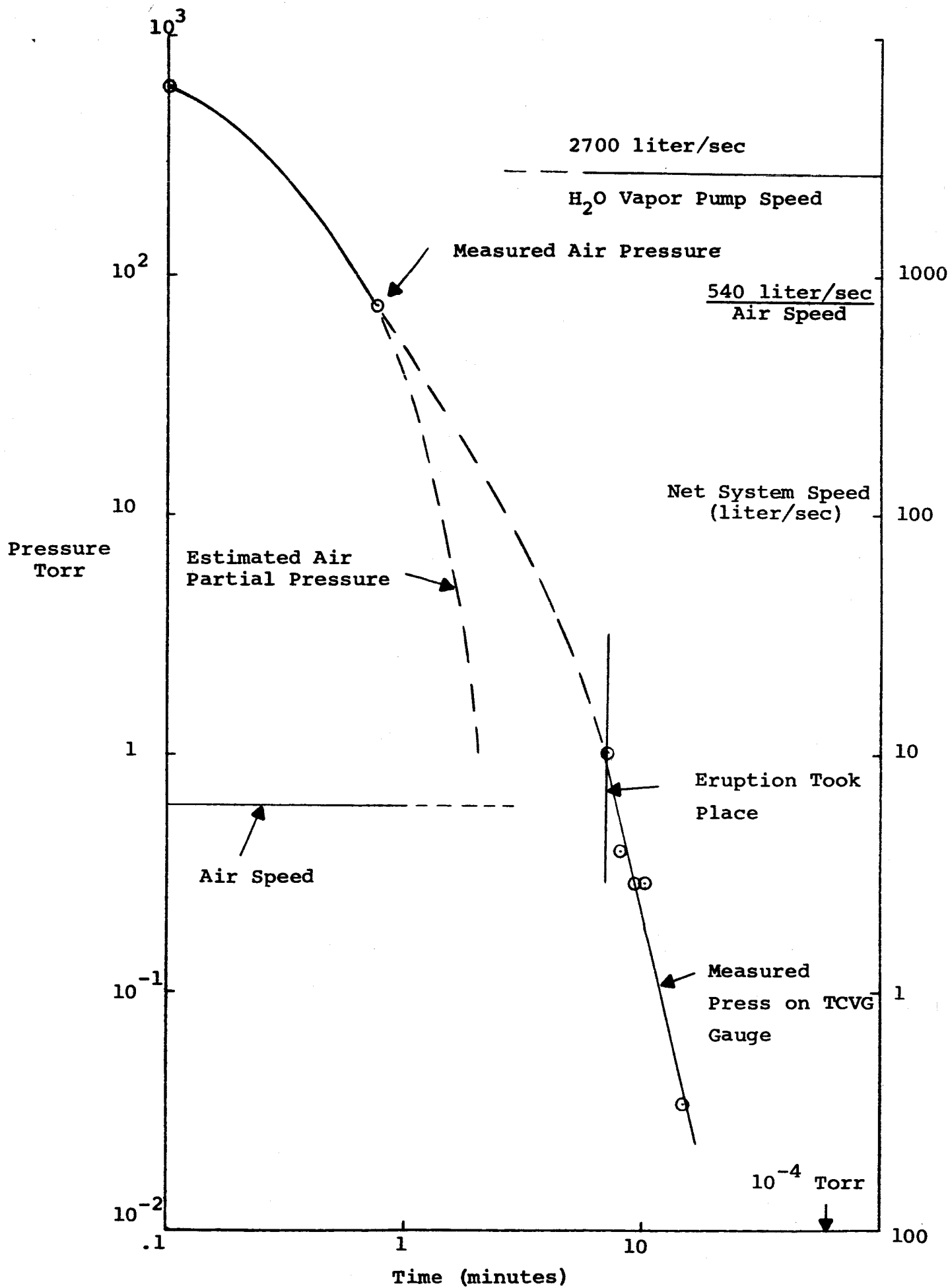


Fig. 6



CLOSEUP OF SOIL SURFACE AFTER ERUPTION



SOIL SURFACE AFTER ERUPTION



PATTERN OF PARTICLES ON SIDE WALLS AFTER ERUPTION